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DE-BOTTLE NECKING POLYETHYLENE PLANT DUE TO BUTENE SHORTAGE: A MULTI-ATTRIBUTE DECISION ANALYSIS USING SMART

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Abstract— The E.P Company supplies the customers with varieties of polyethylene products, to increase production capacity on the Low Linear Density Polyethylene (LLDPE) film grade, De-bottle necking in Reactor-2 (reactor dedicated to produce LLDPE grade) done by changing the condensing agent from Isohexane to Isopentane. Due to the production capacity and reliability on the reactor-2 increase, the demand for raw material Butene increase as Butene use as commonomer in the reactor-2 production. In other hand the Butene plant production decrease because of reduction of cooling capacity and efficiency, this condition create gap on the supply and demand for the Butene. The study objective to be achieved is to find the best solution to overcome Butene shortage problem to produce LLDPE polyethylene with considering the decision maker consideration and at optimize the cost. To achieve that objective, the SMART (Simple Multi Attribute Rating Technique) apply to enable decision maker to gain and increased understanding of his or her decision problem. To fulfill the gap on the supply and demand for Butene, a value tree is created, divided into two component cost and benefit. The study found that the best option for the company is to import Butene from outside (with the condition the new Butene sphere needs to be constructed). This option is recommended for implementation even thought it has the value of benefit at 2nd place (50.9), since a move to the option at 1st place (68.6) is expensive considering that each point increase in the value of benefits would cost $ USD 515,001.4 and at total $ USD 9,115,524/ year. This option also solves the problem, from attributes view.

Keywords: multi-attribute decision analysis, Butene shortage, polyethylene plant

I. INTRODUCTION

"EP Company" was established in 1995, scope of business field is the producer of Polyethylene and Ethylene Glycol, also operate and manage 3 other petrochemical companies established by the shareholders.

The Polyethylene products and Ethylene Glycol are marketed throughout Asia, Africa, Europe and Australia from the several marketing and distribution offices. The "EP Company" utilizes the technology that capable to produce a wide range of commercial products: high-density, medium density or low density polyethylene. The process is capable to swing between LLDPE and HDPE products to fill demand in the market on the high density or low density products using the same reactor, so based on the market condition the production capable to change the products and the volume accordingly. There are 3 reactors available to produce polyethylene: Reactor no. 1 is utilized to produce HDPE, Reactor no.2 is utilized to produce LLDPE and Reactor no.3 is utilized to produce HDPE. In Polyethylene unit, problems encountered in Reactor number 2 which produces Low Linear density Polyethylene using Butene as a commonomer as side branches. Butene from Butene plant production is not sufficient to meet the needs of Butene in the reactor number 2, it started when successful conduct de-bottle necking in reactor 2 by changing the condensing agent from Isohexane to Isopentane. The change on the condensing agent gives advantages to reactor: Increases the production rate from 37 tons/hr to 43.0 T/hr and more (Still there is margin to increased more than 43.0 T/hr), reduced plugging problem on the reactor distributor plate and reduced plugging problem on the cooler.

II. BUSINESS ISSUE EXPLORATION

A. Conceptual Framework

The main raw material for Polyethylene plant in E.P company produce in house, Ethylene and H2 produce in Ethylene plant, Butene produce inside polyethylene plant, Nitrogen produce in air separation unit in the utility area. The Hexene and Isopentane imported from outside because required at small quantity. The advantage from producing in house the raw material are the quality can be maintain as requirement, minimize the contamination as supply in the closed loop, and not effected by disturbance on transportation due to any reason.

Polyethylene becomes a part in human everyday life, from house, in work place, in entertainment place surrounding by polyethylene product. Price of Polyethylene affected by oil and gas price in the market as the upstream raw material of polyethylene comes from oil and gas, depend on the technology they use in Ethylene Plant to crack the oil or gas to produce ethylene which is main component to produce polyethylene. The country which rich oil and gas has the advantages as the raw material is cheap and available in the very big quantity, that why the main producer of polyethylene is Middle East countries likes Saudi Arabia, United emirates, Qatar, Kuwait, Iran which has huge amount oil and gas reserves. Beside of oil and gas price the price of polyethylene affected also with customer behavior. The competitive condition in this business is very high even though the demand for polyethylene product continuous increasing following the economic growth but in same time the new project and the expansion project come on stream, increase supply polyethylene to the market. Due to the increasing market demand on the Polyethylene, the company needs to maximize the utility of their existing assets to increase the output. Study is done to increase Reactor-2's production capacity with minimum investment. To increase the reactor production capacity on the LLDPE reactor, the condensing agent was changed from Isohexane to Isopentane. Additional facilities, such as Isopentane sphere tank for storage and Isopentane degassing column for purification, were constructed to facilitate the condensing agent changed from Isohexane to Isopentane.

Marketing and sales for the Polyethylene product are divided into 5 regions: Europe, Middle East - Africa, and other areas are handled by Head office; Asia Pacific - North East Asia customers are handle by Hongkong marketing office, and Asia Pacific - South East Asia are handled by Singapore marketing officer. Asian market is the main destination of company product, where China has significant impact on the global Polyethylene trade as China major customer polyethylene in Asia.

B. *Method of Data Collection and Analysis*

This final project based on business problem occurred in the Polyethylene unit, Reactor-2 not capable to continuous produce LLDPE polyethylene as per dedicated. This Butene shortage problem needs to be solved in order to maximize company profitability. The Final project objective to be achieved is to find the best solution to overcome Butene shortage problem to produce LLDPE polyethylene with considering the decision makers' needs and preferences as well as at the optimum cost. To achieve that objective, the SMART (Simple Multi Attribute Rating Technique) is applied to enable decision maker to gain and increased understanding of his or her decision problem. The SMART utilized in this project because of:

a) Allowing complex problems to be decomposed into sets of simpler judgments and provides documented rationale for the choice of a particular option.
b) Multi attribute approach to address the problem more effectively, that will help decision makers to better understand the issues associated with the problem involved. Ultimately, better quality decision will result.
c) The simplicity of both the responses required of the decision maker and the how these responses are analyzed.

A value tree is created to address shortage of Butene and divided into two component cost and Benefit.

Cost consists of: New facility, Loss of production, cost for buy production raw material. Benefit consists of: a market demand on favorite type of the product, customer satisfaction on delivery, raw material continuity, production comfort, and asset utilization. The survey conducted to know the decision makers preferred on the attributes, measured in weigh %. The survey is also conducted to determine which is preferred by decision maker on every attributes to the options available, measured in weight %. The weight on every options VS their cost, plotted in the graphic to find which option giving maximum value with optimum cost.

C. *Analysis of Business Situation*

Three reactors are available for the production of polyethylene with a wide variety of products, from low linear density to high density polyethylene:

Table 1. Reactors and Product produce

Reactor	PE Product Type	Mode of operation	Catalyst Type
1	High Density	Dry Mode	Cr base catalyst
2	Low Linear Density	Condensing Mode	Ti base catalyst
3	High Density	Dry Mode	Cr base catalyst

The problem occurred in the Polyethylene unit, Reactor-2 not capable to continuous produce LLDPE polyethylene as per dedicated. This problem happened since April 2009, when condensing agent in Reactor-2 changed from Isohexane to Isopentane, the results are: Reactor-2 capacity increase from 37.0 Tons/hr to 43.0 Tons/hr and reactor forced shutdown for cleaning is reduced. Reactor-2 using Butene as commonomer, the Butene produced in Butene unit. Due to Reactor-2 capacity increase the Butene consumption for production also increase, in other hand Butene reactor production capacity is reduced due to reduction of cooling capacity since more tube on cooler sealed due to puncture during cleaning. The Butene shortage forced Reactor-2 production swing to produce HDPE grade or shutdown.

The possible cause of problem that, has made Reactor-2 incapable to continuously produce LLDPE polyethylene as per dedicated is the bottle neck in the LLDPE reactor, due to the increase in the reactor's production rate that is not followed by the debottlenecking of the Butene plant so that the Butene plant is not able to produce Butene as per requirement of Reactor-2.

III. BUSINESS SOLUTION

A. Alternative of Business Solution

In this final project the SMART analysis (Goodwin and Wright 2004) is applied to enable decision maker to gain understanding of his/her decision problem when decisions involving multiple objectives.

Value focus thinking is applied to channel critical resource- hard thinking in order to make better decision, the greatest benefits of value focus thinking are being able to generate better alternatives for any decision making (Keeney and Raiffa 1992).

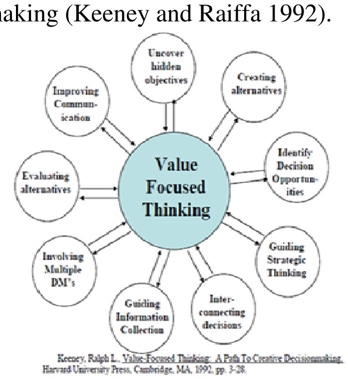


Figure 1. Thinking about values: The Basis of Quality Decision Making (Source: Keeney and Raiffa 1992)

The business issue is explored and analyzed with the condition and assumptions:

a) The Reactor -2 Production rate 43.0 Tons/hr, maximum production rate of reactor-2 which has been proven after condensing agent change from Isohexane to Isopentane.
b) The downstream of Reactor-2 is able to handle production 43.0 Tons/hr without any problem.
c) Ethylene units are able to supply ethylene for reactor-2 production 43.0 Tons/hr.

To measure the performance course of action in relation to the objectives of decision maker, need to set the attributes which can assesses on the numeric scale.

A value tree for the Butene shortage problem constructed with attributes that used to measure the performance of courses of action in relation to the objectives of decision maker.

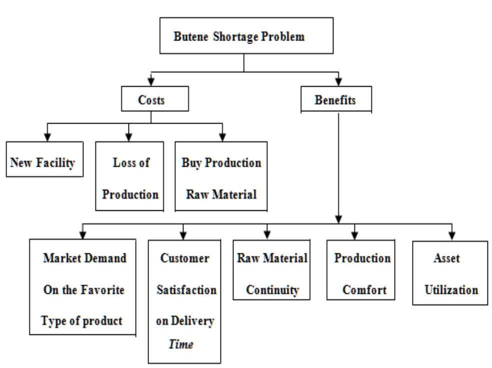


Figure 2. Value tree for Butene Shortage Problem

The value tree used in this study consists of benefit and cost. There are five attributes of the benefits: (a) market demand on the favorite type of product (product easy to sell as high demand on the type grade in the market); (b) customer satisfaction (product arrive to customer as per agreement); (c) raw material continuity (continuity of supply of raw material for production); (d) production comfort (operation choice, product easy to produce, less problem); and (e) asset utilization (maintain highest possible utilize asset to produce product).

To fulfill the gap on the supply and demand for the Butene or alternate raw material for Butene which the final product can be easily sold in the market or demanded by customer, the options are:

Option A: Replace the 3 pairs of Butene reactor cooler,
Option B: Replace 1 of Hexane tank material with Hexene (so the reactor-2 can produce LLDPE resin Hexene grade),
Option C: Import Butene from outside,
Option D: Shutdown the reactor-2 when shortage Butene,
Option E: Produce High density product.

B. Analysis of Business Solution

The weights for the attributes in the value three and options perform on the attribute, taken by conducting survey to several advisors and engineers who are in charge for the operational and technical development of the factory. The selection of respondent on this survey is purposive sample, sampling targeted to particular group. The group selected based on their responsibilities which is involve to solve the Butene shortage problem. By only selected the specific person that know and understand the problem, the expectation is result more accurate. Attribute weight and weight on the options performs on the attribute data taken from the survey to aggregate benefit from every options/choices.

Attribute	Weight %	Option				
		A	B	C	D	E
Market Demand	28	13	33	32	36	63
Customer Satisfaction	11	38	34	66	35	25
Raw Material Continuity	26	29	41	63	5	85
Production Comfort	9	42	47	42	68	36
Asset Utilization	26	39	58	56	5	88
Aggregate Benefit		29.3	43	50.9	22.7	68.6

Annual costs on the every option calculated: New Facility Cost (Capital expenditures + Operational Expenses additional equipment), Annual loss of production and Annual addition cost to buy production raw material.

Table 3. Cost associated with option

Opt	New Facility Cost ($)/year	Loss of Production ($)/year	Buy Raw material ($)/year	Total Cost and loss ($)/year
A	90,000	40,719,923	0	40,809,923
|B	0	30,110,336	3,234,600	33,344,936
C	104,100	44,539,053	894,600	45,537,753

D	0	59,016,065	0	59,016,065
E	0	11,706,663	1,272,341	12,979,004

After plotting of benefits against annual cost for the options (see Figure 3). The option E (Produce High density product) is dominant to others option due to having highest value of benefits (68.6) and having lowest total annual cost and lost per year ($ USD 12,979,004). But the objectives of this final project is

Hexane tank with Hexene) which have value of benefits at 2nd place (50.9) and 3rd place (43) respectively. Potential problem analysis conducted to improve understanding from the three options: Produce High density product, Import Butene from outside and Replace 1 of Hexane tank with Hexene.

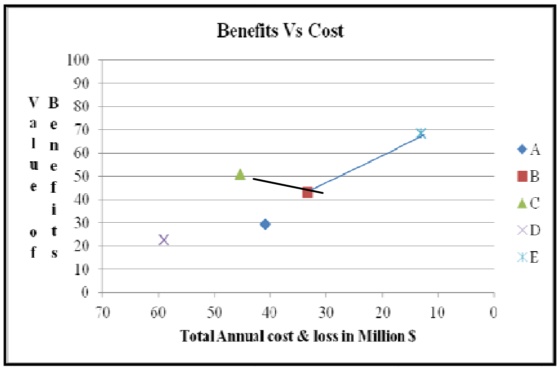


Figure 3. A Plot of benefits against annual cost for the options

After Applying the SMART analysis on the Butene Shortage problem on the "E.P Company" and trading off between benefits and cost. Potential Problem Analysis is also done on the three best options: Produce High density product, Replace 1 of Hexane tank material with Hexene and Import Butene from outside. The recommendation to solve Butene shortage problem to choose option **import Butene from outside** which having the benefit rank in the second place (50.9), and at 1st rank option **produce high density product** (68.6): choosing the option import Butene from the outside with the condition the "new Butene sphere" (Option C+) needs to be constructed so the annual loss of production become zero as the Butene shortage can be covered by importing Butene so the reactor continuously running to produce LLDPE product.

The advantages of choosing the option C+, from attributes view are (a) to fulfill market demand on the favorite type of product as Reactor-2 continuously producing low density dedicated polyethylene product rather than the high density product, which is difficult to be absorbed by market; (b) to fulfill customer satisfaction on time delivery time as Reactor-2 produce same grade that promised to customers; (c) to maintain the raw material supply; (d) by having dedicated tank for imported Butene it is easier for planning to maintain availability for Butene; (e) to fulfill production comfort as the reactor will be producing the same product grade, thus does not

to find the best solution to overcome Butene shortage problem to produce LLDPE polyethylene with considering the decision makers' needs and preferences as well as at the optimum cost therefore value focus thinking applied to channel critical resource- hard thinking in order to make better decision. The alternatives chosen is option C (Import Butene from outside) and option B (Replace 1 of

require product transition; and (f) high asset utilization due to no reactor shutdown and less potential for emergency shutdown due to problem in transition.
In addition, the option to replace the 3 pairs of Butene cooler that is to be implemented will help to reduce the quantity Butene import by 1137.427 tons.

Table 4. Cost for option C+ (Import Butene from outside plus New Butene sphere constructed) VS Option E (Produce high density product)

Opt	**New facility Cost ($)/year**	**Loss of Production ($)/year**	**Buy Raw material ($)/year**	**Total Cost and loss ($)/year**
C +	216,600	0	3,646,879	3,863,479
E	0	11,706,663	1,272,341	12,979,004

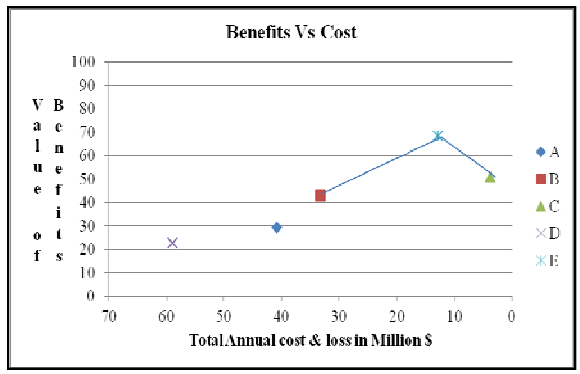


Figure 4. A Plot of benefits against annual cost for the options after adding the new Butene sphere constructed for the option C.

Sensitivity analysis is conducted on two best options, which are Option E (Produce High density product) and Option C+ (Import Butene from outside plus New Butene sphere constructed). A move from C+ to Option E would lead to an increase in the value of benefits from 50.9 to 68.6, which is an increase of 17.7 points. This move also lead to an increase in costs from $ USD 3,863,479 to 12,979,003, whis is an increase of $ USD 9,115,524. Therefore each one point increase in the value of benefits would cost $ USD 9,115,524 / 17.7, which is $ USD 515,001.4. Considering the high cost of moving from Option C+ to Option E, this may not be preferred by the company.

IV. Conclusion and Implementation Plan

The study found that the best option for the company is to import Butene from outside (with the condition the new Butene sphere needs to be constructed). This option is recommended for implementation even thought it has the value of benefit at 2nd place (50.9), since a move to the option at 1st place (68.6) is expensive considering that each point increase in the value of benefits would cost $ USD 515,001.4 and at total $ USD 9,115,524/ year. This option also solves the problem, from attributes view, which are: (a) fulfilling market demand on the favorite type of product as reactor-2 continuous producing dedicated Polyethylene product (LLDPE product); (b) fulfilling customer satisfaction on time delivery time as Reactor-2 produces the same grade that was promised to customers; (c) maintaining the raw material continuity; (d) fulfilling production comfort as running in the same product grade; (e) asset utilization is high due to no reactor shutdown, also less potential for emergency shutdown. In addition, the option to replace the 3 pairs of Butene cooler is also to be implemented to reduce the quantity Butene import by 1137.427 tons.

The implementation plan for the option of importing Butene from outside (with the condition the new Butene sphere needs to be constructed) with timeframe 1 year and total man hour 12,936 hour (permanent employee only) is presented in the Gantt Chart presented in Tables 5, while the implementation plan for the replacing the 3 pairs of Butene reactor cooler: timeframe 9 months and total man hour 5,060 hour (permanent employee only) is presented in Table 6.

Table 5. Gantt chart for new Butene sphere, Butene degassing column and Butene dryer construction

No	Implementation action	Dept. Involve
1	Engineering phase	
	a. Design	Eng,Tica
	b. Site evaluation	Const,Eng,Prod
	c. Final design & site evaluation	Eng,Tica,Const,prod
2	Find the contractor	
	a. Value of project evaluation	Fin,Eng, Const
	b. Project tender	Eng,const
3	Fabrication	
	a. Equipment Fabrication	Eng,const
	b.Equipment delivery	Eng,const
4	Construction	
	a. Civil work	Eng,const, Prod,sft
	b. Erection of Equipment	Eng,const, Prod,sft
	c. Finishing	Eng,const, Prod,sft
5	Commisioning	
	a. Intrumentation checking	Prod,Tica,Maint
	b. Equipment checking	Prod,Tica,Maint
	c. Equipment cleaning & testing	Prod,Maint
6	in operation	Prod

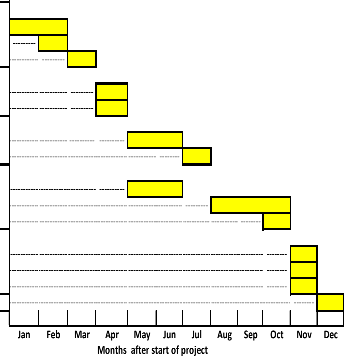
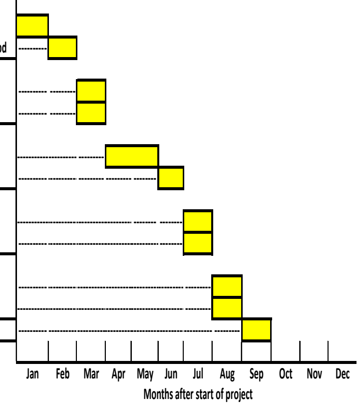


Table 6. Gantt chart for replacing the 3 pairs of Butene cooler

No	Implementation action	Dept. Involve
1	Engineering phase	
	a. Design	Eng,Tica
	b. Final design evaluation	Eng,Tica,const,prod
2	Find the contractor	
	a. Value of project evaluation	Fin,Eng, Const
	b. Project tender	Eng,const
3	Fabrication	
	a. Equipment Fabrication	Eng,const
	b.Equipment delivery	Eng,const
4	Commisioning	
	a. Equipment checking & testing	Prod,Const,Maint
	b. Equipment cleaning	Prod,Maint
5	Instalation	
	a. Installation of Equipment	Prod, maint
	b. Preparation for operation	Prod, maint
6	in operation	Prod



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